An Introduction to Systems Modeling

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Mathematical Modeling

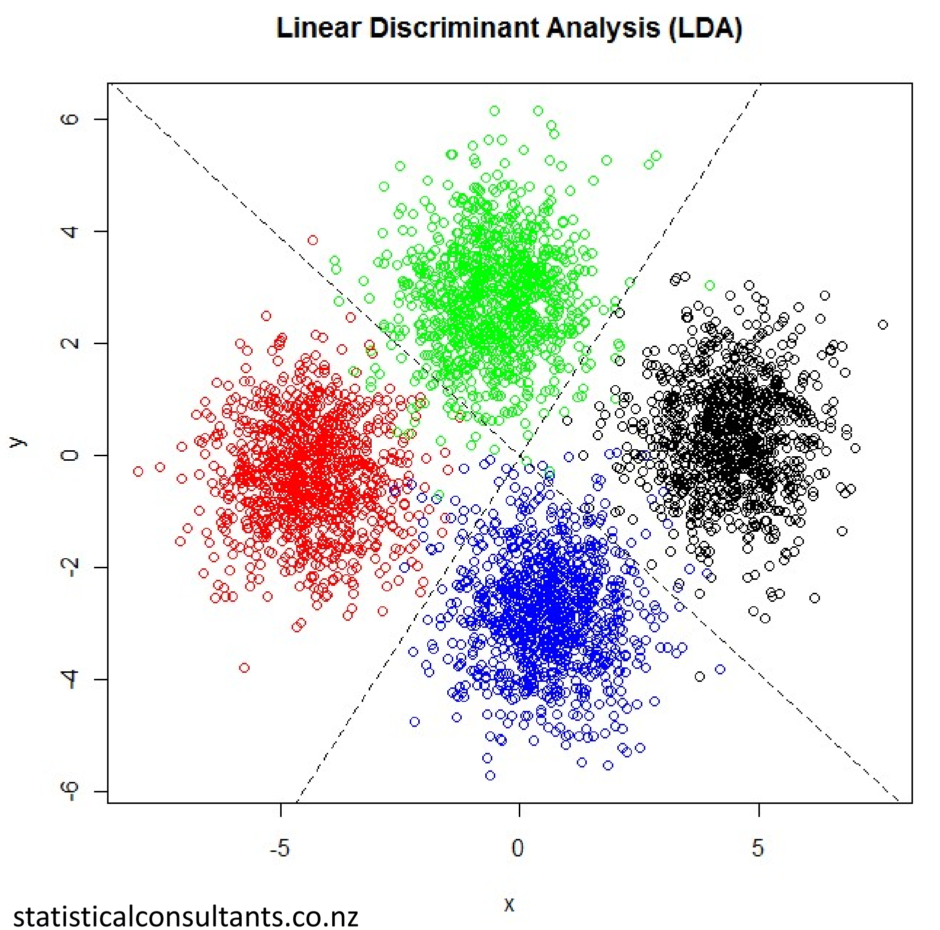
- Also called Numeric Modeling
  - Simplification of reality
  - Based on available knowledge of system
  - Attempt to simulate a system using mathematical relationships

"All models are wrong but some are useful"

- George Box

Types of Models: Empirical

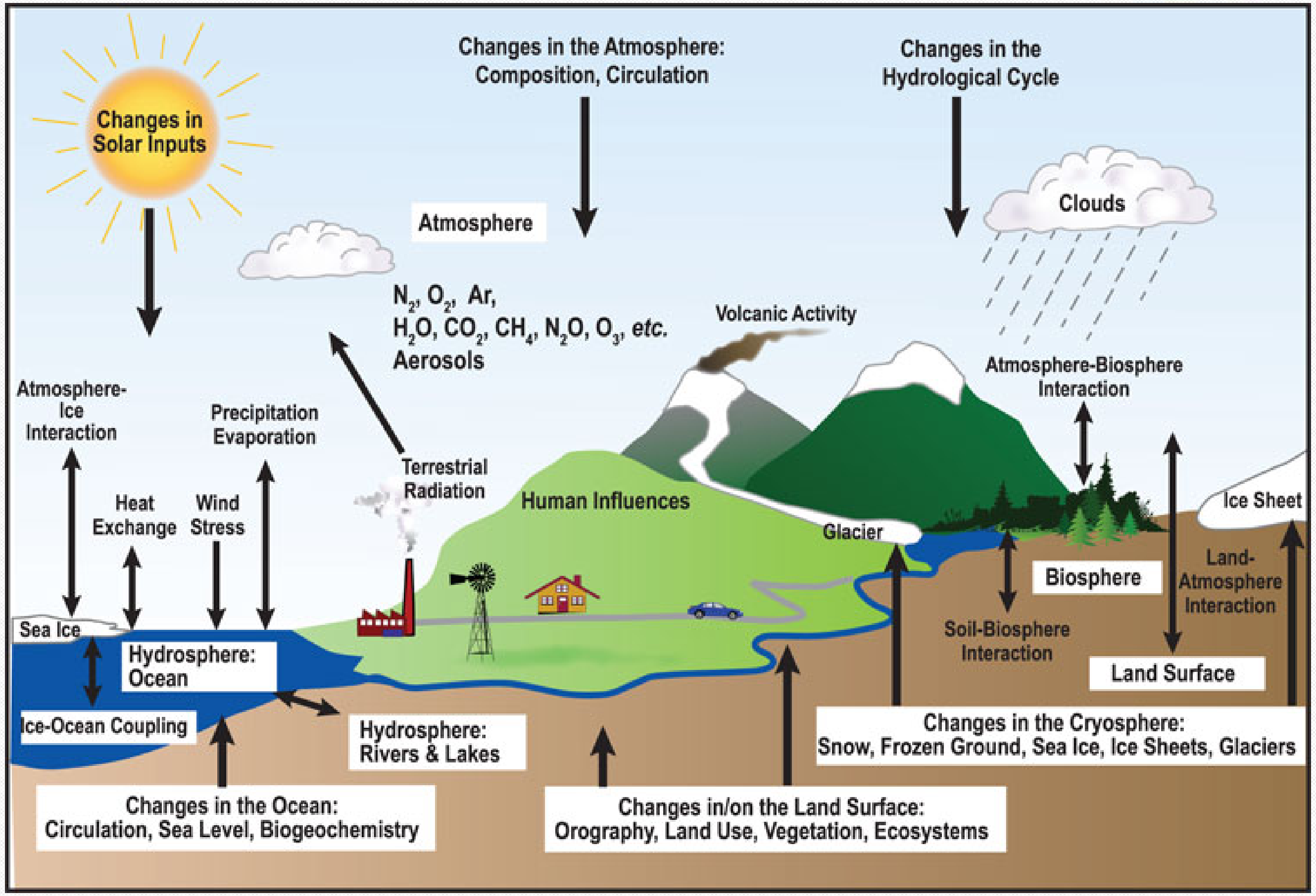
- Empirical Models
  - Inductive reasoning
  - Generally based on statistics/observations
- Many varying methods
  - Regression analysis
  - Composite analysis
- Often requires training and evaluation datasets



statisticalconsultants.co.nz

Types of Models: Process Based

- Process Based
  - Deductive reasoning
  - Based on laws or theories
- Examples
  - Weather/climate models
  - Disease transmission models
- Evaluated against observations



http://blogs.scientificamerican.com/the-curious-wavefunction/are-more-accurate-climate-change-models-worse/

Model Comparison

Empirical	Process Based
Based on observed data	Based on theories
Does not require apriori knowledge	Required detailed knowledge of the system
Extrapolation is unreliable	Novel conditions can be simulated
Most relationships are linear	Relationships can be both nonlinear and linear
Robustness analyzed through Monte Carlo approaches	Sensitivity analysis through parameter testing

Model Classifications

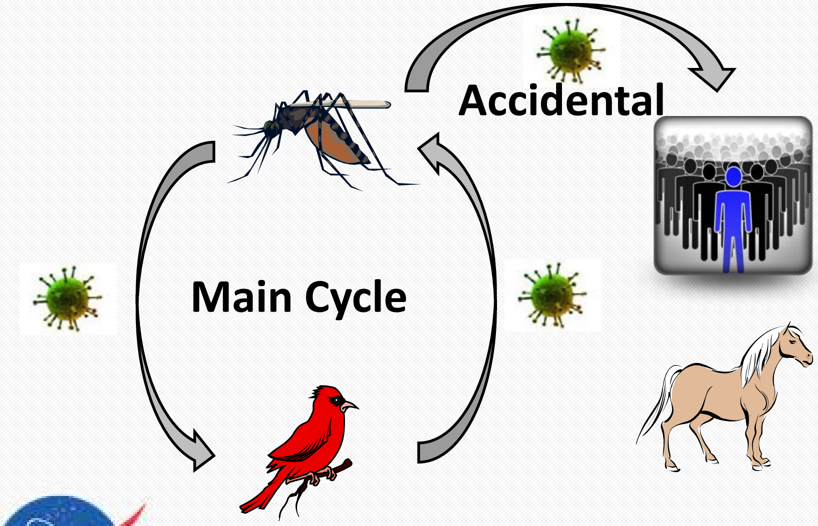
- Stochastic = Some random component
  - Every run will yield a unique result
- Deterministic = Non-random
  - Every run yields the same result
- Static = Time independent
- Dynamic = Time dependent
- Many more…

What is a System?

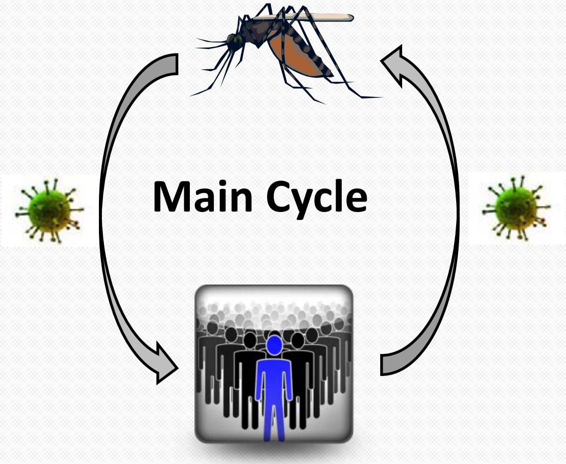
- "A system is an interconnected set of elements that is coherently organized in a way that achieves something."

  \- Donella H. Meadow

West Nile Virus Ecology



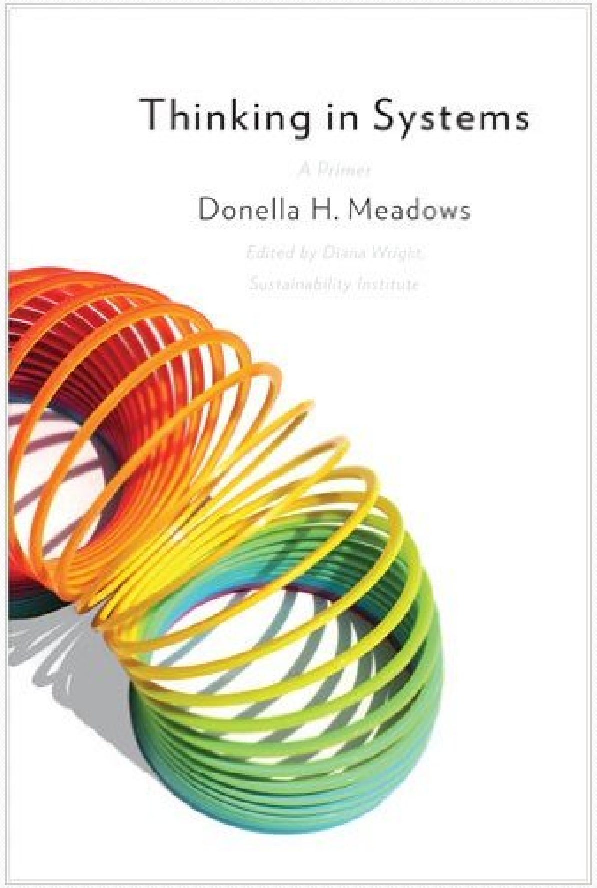
Dengue Virus Ecology



- Elements
- Interconnected
- Purpose/Function

Why think in systems?

- Most “things” we study are not independent of other “things”
- Even simple systems can display complex behavior
- A holistic approach can yield knowledge unattainable by studying individual elements



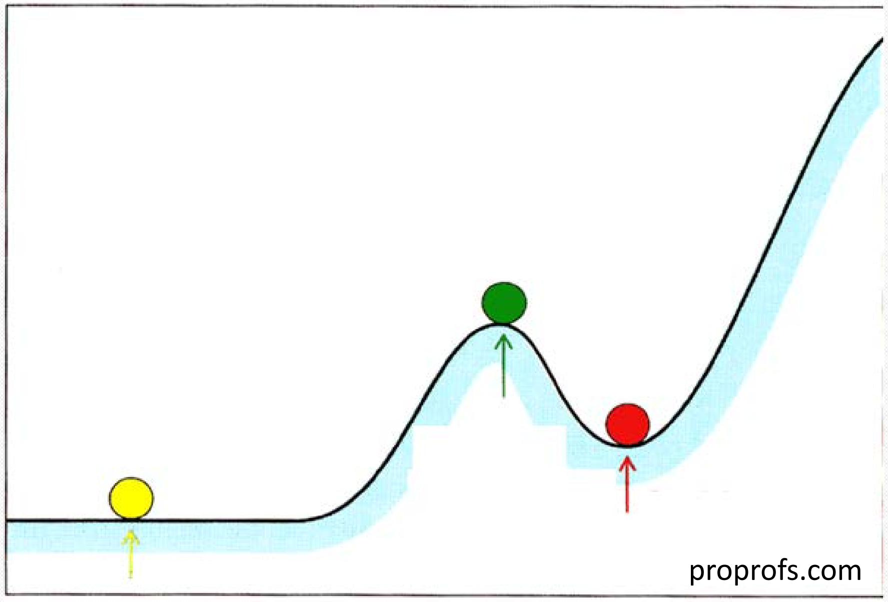
Important Concepts

Equilibrium

- Input=Output

Dynamic Equilibrium

- Input=Output (nonzero)



Neutral Equilibrium

- Equilibrium movement is dependent on perturbation size

Stable Equilibrium

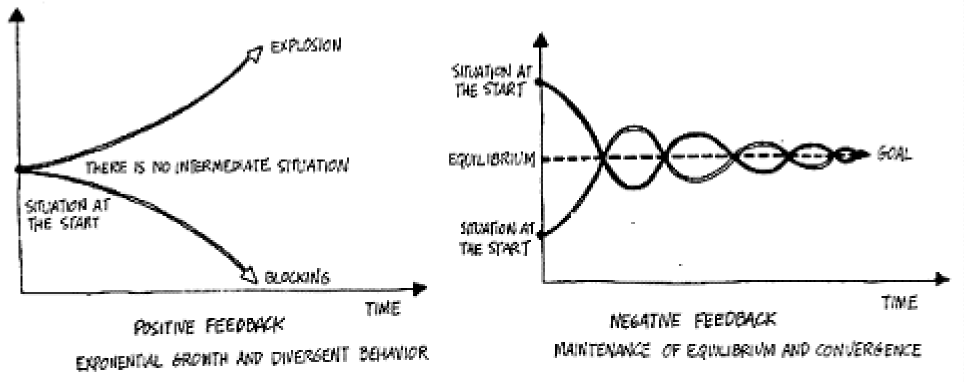
- Perturbation to the system will result in a return to equilibrium

Unstable Equilibrium

- Perturbation to the system will result in movement to a new equilibrium

Feedback Loops

- Stock size regulating in/out flows
- Positive feedback loops
  - Propagating feedback in the system creating a runaway effect
- Negative feedback loops
  - Limiting feedback in the system causing a return towards equilibrium



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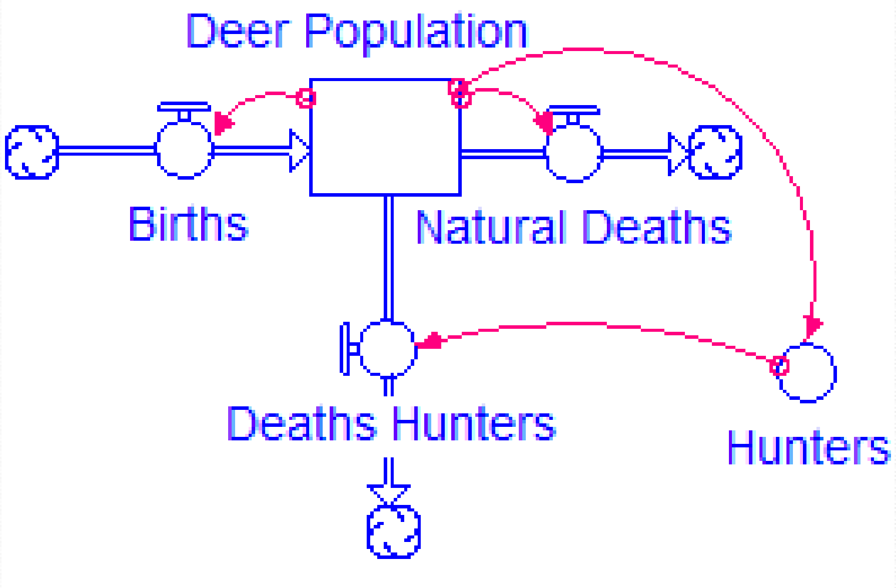
Model Basics

- System Models Consist of…
  - Stocks/Reservoirs: An accumulation of something
    - Could be a population, energy, or even information
  - Flows: Input and output of the stocks
    - Could be deaths/births, heat, ect.
  - Equations: Equations/constants



Example Model